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ARS SPECIAL REPORT

Witchweed

ARS 22-41

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U. S. DEPARTMENT OF AGRICULTURE

June 1957

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

WITCHWEED is a plant parasite newly identified in the United States. It is important because of its potential threat to the Nation's leading summer grass and grain crops. It entered the country from the Eastern Hemisphere, nobody knows when or how. Only known infestation in the United States is in eight counties of North Carolina and South Carolina.

Methods of control include the use of cultural and chemical practices, quarantine, and cleanliness of containers, farm equipment, and vehicles.

Federal and State quarantines are being put into operation; a survey is being conducted to determine how far the pest has spread; and research has been started to develop more knowledge of the parasite.

Because of a lack of information on witchweed in the United States, assistance has been requested from other countries. The Governments of the Union of South Africa and the Anglo-Egyptian Sudan have assisted generously in providing research findings and other information.

A color drawing of witchweed is included in PA-331, Watch Out for Witchweed, prepared for popular distribution by the Agricultural Research Service in cooperation with North Carolina State College and Clemson Agricultural College, South Carolina. Copies may be obtained on request from the Office of Information, U.S. Department of Agriculture, Washington 25, D.C.

Information in this report was provided by the Crops Research Division, the Plant Pest Control Division, and the Soil and Water Conservation Research Division, Agricultural Research Service; the North Carolina Agricultural Experiment Station; and the South Carolina Agricultural Experiment Station

WITCHWEED

WITCHWEED (Striga asiatica), a parasitic plant that attacks corn, sorghum, sugarcane, crabgrass, Johnsongrass, and other plants of the grass family, was identified in 1956 in eight counties of North Carolina and South Carolina. Surveys are being continued to see whether the weed exists in other localities. Long known in the Old World tropics and subtropics, this is witchweed's first recorded appearance in the Western Hemisphere. No one knows how it was introduced into this country.

Considering the high economic value of susceptible crops in the United States and the sometimes devastating effect the plant parasite can have on them--it may amount to complete loss of a corn crop in instances of heavy infestation--witchweed is a pest of potentially great importance. Steps are being taken to institute State and Federal quarantines to prevent spread of the weed. Research is being started in this growing season of 1957 to provide knowledge about witchweed that can be used in a program of eradication or control.

Major difficulties attend efforts to eradicate witchweed. A single plant can produce 50,000 to 500,000 tiny seeds that can barely be seen by the naked eye and can be moved by wind and water, and in soil carried from the fields. The seeds may lie in the soil for 20 years waiting for a host. They germinate when stimulated by emanations of "host extract" from nearby roots, mainly of host plants. Getting the millions of tiny seeds in the soil to germinate and destroying the plants before new seed can be produced is one of the few known methods of dealing with the pest.

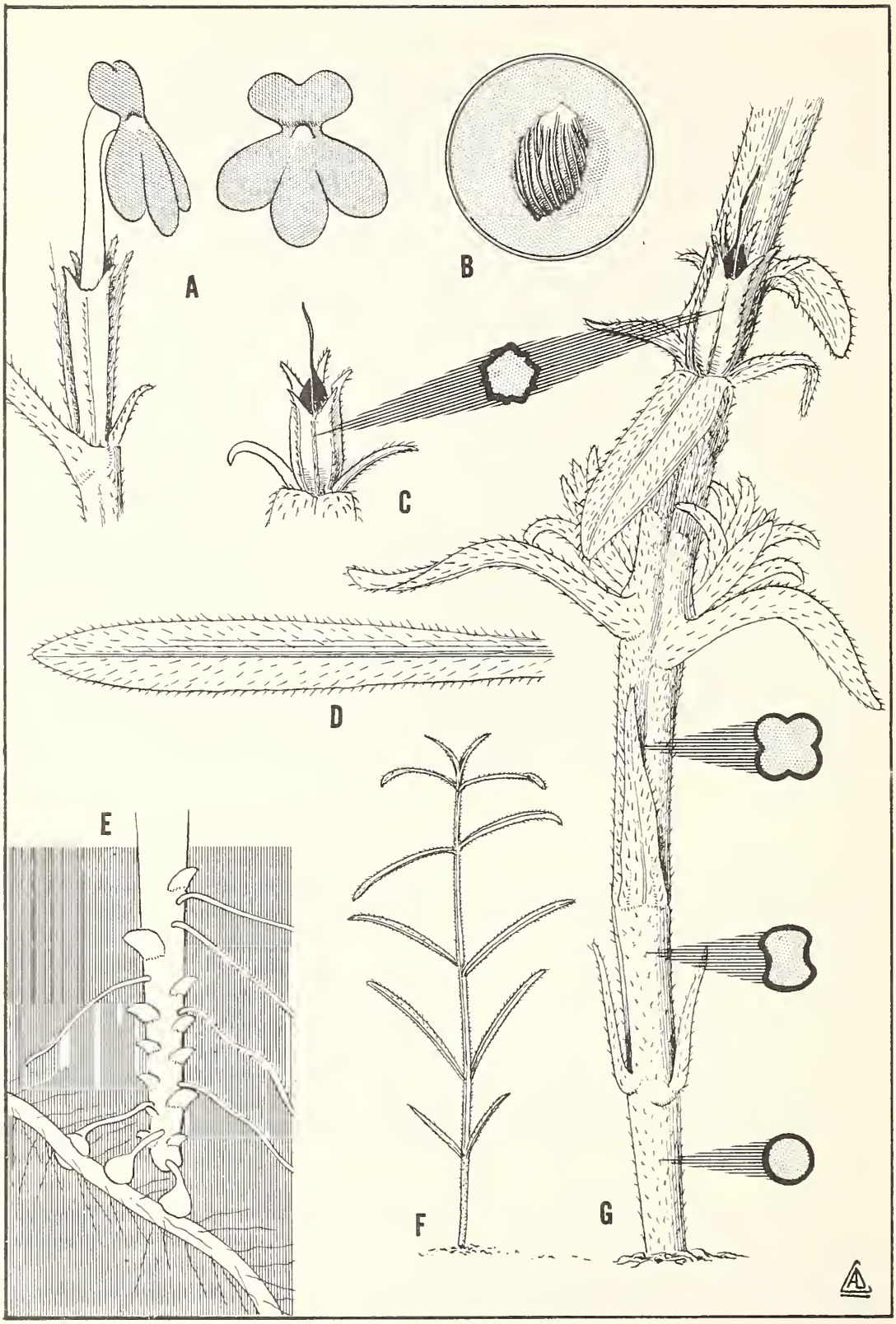
The genus Striga has been known and written about in Africa, Asia, and Australia since 1790. In order to learn whether the plant behaves the same in the United States as in its previously known habitats, scientists will have to repeat in this country at least some of the experimentation done elsewhere. New experiments will also be undertaken in an effort to find ways to combat the pest under U.S. conditions.

DISCOVERY AND SURVEY

A MYSTERIOUS "disease" of corn that caused stunting of the plants and appeared similar to drought damage was first reported in Horry County, South Carolina, August 29, 1951, and later in Robeson and Columbus counties, North Carolina. In July 1956 affected corn plants were sent to North Carolina State College for examination. No bacterium, virus, nematode, fungus, or mineral deficiency was found that could account for the trouble. However, attention was directed to a weed by a graduate student from India who was assisting with the examination and noticed underground stems among the corn roots that resembled those of a parasitic Striga species that attacks sugarcane in the Eastern Hemisphere. Identification of the plant as witchweed soon followed. Farmers in the infested area believe it has been present since 1950, though some place their initial observation as early as 1946.

The Agricultural Research Service, U.S. Department of Agriculture, was notified September 21, 1956, of witchweed's appearance in North Carolina.[1]

[1] First published account of witchweed's occurrence in the Western Hemisphere appeared in The Plant Disease Reporter, an Agricultural Research Service periodical, in its issue of October 15, 1956.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A meeting of interested parties was held October 2. In spite of the lateness of the season, a quick survey of the weed's occurrence was inaugurated. Officials of the two States and the Department of Agriculture began their survey October 15 and ended it November 2, when the weeds had died or deteriorated too much for good identification.

This brief survey revealed 117 farms infested in the two States: 79 farms in four counties of North Carolina--Bladen, Columbus, Cumberland, and Robeson--and 38 farms in four counties of South Carolina--Dillon, Horry, Marion, and Marlboro. Nearly all of the infestation was in corn, but one field of milo sorghum had been invaded. The infested counties are generally contiguous along the boundary of North Carolina and South Carolina near the seacoast.

A more thorough survey is planned for the growing season of 1957.

THE PARASITIC PLANT

INFORMATION about witchweed derives almost entirely from other countries. Its life history, research information, and such methods of control as are known all come from scientific literature abroad.[2] U.S. scientists and observers have had no experience with the plant except in the interval since it was recognized and its effects on crops observed over a period of years.

The witchweed is a deceptively pretty plant, with bright green stem and leaves and showy nasturtium-red flowers having yellow centers. The blossoms are shaped somewhat like violets. The weed grows 6 to 12 inches high, occasionally as tall as 18 inches. Witchweed has multiple branches, both near the ground and higher on the plant. The leaves are relatively long and narrow, not much wider than the breadth of the stem. Both leaves and stem have a fuzzy appearance. The leaves are in pairs, emerging from the stem almost opposite each other. The next pair of leaves grows from the stem at a 90-degree angle to the first, and the pairs continue to alternate in this fashion. (See fig. 1.)

Flowers appear just above the leaf attachment to the stem. As the stem grows and branches, more flowers come into bud, and the plant continues to bloom and produce seed pods throughout the season. The multiplicity of red flowers no doubt prompted the two Afrikaans names for the plant, rooi-bloemetjie (little red flower) and vuurbossie (firebrand). The seed pods or capsules are five-sided and each side terminates in a characteristic spur. The seed capsule contains about 1,350 tiny brown seeds, each of them measuring about 1/5 millimeter in length. It would take 6 seeds laid lengthwise to span a period in ordinary print and 125 to measure 1 inch. They are about three-fifths as wide as long. (See fig. 2.)

[2] This report has leaned most heavily on A.R. Saunders' Studies in Phanerogamic Parasitism with Particular Reference to Striga lutea Lour. (a species of witchweed closely related to if not identical with Striga asiatica), published in 1933 by the Department of Agriculture, Union of South Africa, and on The Genus Striga, A Study in Plant Parasitism and Its Control, an unpublished paper loaned by its author, K. Wilson Jones, senior economic botanist, Anglo-Egyptian Sudan. Additional material was also obtained from the Government of the Union of South Africa.

← Figure 1.--Witchweed (A) flower; (B) seed, magnified 200 times; (C) seed pod, with cross-section of five-sided pod; (D) leaf; (E) root, showing haustoria or sucking organs attached to a host root; (F) young plant; (G) adult plant, with shape of first three nodes of stem indicated by cross-sections at right. All magnifications (except seed) about 4 times natural size.

Figure 2.--Witchweed seeds magnified about 650 times. Detail of seed covering, lower left.

The mature dark-brown seed capsule bursts open about 1 month after flowering, while blossoms are still appearing higher on the plant. Thereafter, as more pods mature, any motion of the weed spills myriad seeds into the soil. One plant, depending on its size, can produce 50,000 to 500,000 seeds. The larger number is enough seeds, if laid end to end, to reach more than 330 feet. In heavily infested areas, the seeds may be distributed in the soil, to a depth of 9 inches, in numbers from 50,000 to 3 million per square yard.

The watery white witchweed root is round in cross-section. It has no root hairs, depending for its sustenance on the roots of the host plant. The underground part of the stem has a series of scales placed similarly to the leaves above ground. Between ground surface and the third node of the stem the shape of the cross-section gradually changes, and the rest of the stem is "square," modified by rounded corners and an indentation on each side.

Germination

Witchweed seeds generally require a rest period of 15 to 18 months before germination, although some seeds begin to develop before the period is up.

Most seeds germinate only after the roots of a host plant (or one of a few others) have started growing and have released a "host extract" in the soil. This is the chemical signal for witchweed seeds to come to life. They must be quite near the host roots, however--as close as 3 or 4 millimeters (one-tenth to fifteen-hundredths of an inch). This close association is not so rare in soil laced with a network of growing rootlets and root hairs of a plant such as corn, considering the multitude of tiny Striga seeds scattered through the earth in infested fields. The "host extract," which is believed to be a hormone-type secretion, serves both as a stimulant to the germination of witchweed seeds and as a guide for its roots to follow to the host root. This chemical guide also shows the way for secondary roots of the pest to tap other roots of the host.

Research workers in North Carolina and in South Africa have been able to germinate a small percentage of the seeds in the absence of a host or "host extract."

The "host extract" has been chemically tested in Africa and has been found to bear a close resemblance to some forms of sugar. Thirty chemical forms of sugar were tried as germination stimulants and one, d-xyloketose, caused "spectacular" germination activity. The literature does not indicate that any of the sugars have been used in the field as a means of witchweed germination and eradication.

Laboratory experiments have shown that witchweed seeds germinate best after they have been pretreated by soaking in water for 6 to 24 days at temperatures below 22°C. (71.6° F.) and before they are exposed to the "host extract." In the field, therefore, 1 to 3 weeks of warm rainy weather before the young corn or other host plant begins good root growth should result in a high degree of germination of witchweed seeds in the soil. On the other hand, North Carolina tests reveal that saturated or water-logged soil completely inhibits germination.

In the absence of a host, the seeds may lie dormant in the ground for 20 years awaiting the stimulus to germinate them.

Growth

Upon germination, the witchweed rootlet grows directly toward a root of the host plant. As soon as it touches the host root, the tip of the parasitic rootlet swells into a conical or bell-shaped form and presses the large end of the cone against the host root. What happens during the next 8 to 24 hours is a combination of mechanical pressure and chemical actions. The advance cells of the parasitic root give off a ferment that softens or dissolves the cell walls of the host tissue. As penetration continues, the cone puts out fingerlike tubes that reach into the vascular bundles or nutrient pipelines of the plant. Now it has access to the juices, plant foods, and minerals absorbed or manufactured by its host. Its root starts branching soon after germination, sending out "innumerable" tentacles to feed upon accessible roots. Where the Striga root runs closely parallel to a host root, as many as 9 rootlets have been counted attached to a section of corn root a quarter of an inch long.

Meantime other seeds are germinating. They may be very numerous in a small area of the soil, and may all direct their attack on one plant. An extreme case observed in South Africa showed no fewer than 20 witchweed seedlings attached to about a quarter of an inch of a young corn root. In

heavily infested fields, as many as 500 witchweed plants may parasitize the roots of a single host; comparatively few of this number survive to reach the surface because one host plant cannot support so many.

During this early part of its life, while its white roots are penetrating underground and sapping the means of life from another plant, the witchweed is a full-fledged parasite. About a month (it may be 3 to 8 weeks) after germination of the seed, the plant appears above ground. It quickly develops a green stem and leaves and grows like other plants, manufacturing plant food by means of its own chlorophyll. It is no longer a full parasite but a semiparasite, still depending on its host to furnish water and minerals but not organic material. As a semiparasite it continues to the end of its annual life cycle.

From germination to first seed production in a given year is about 3 months. It germinates about 2 weeks after planting of the host species. The first month, approximately, is spent underground. A few weeks after emergence from the ground, the plant begins to flower. In a month or less the seeds begin to ripen. Flowering and fruiting are continuous until death of the plant.

Spread

The witchweed has no built-in mechanism for the dispersal of seeds, except the swaying motion of the parent plant in the wind. But the extremely light weight of the seeds facilitates their spread by such natural agencies as wind and water. In South Africa they have been known to spread as far as 7 miles in a windstorm. The extent of spread by means of water has apparently never been measured.

Since the seeds drop to the ground and mingle with the earth, anything that carries soil or dust can also carry these almost microscopic seeds. They can be spread in the field by the movement of soil along rows or from field to field by farm implements and machinery. They can mingle with the soil adhering to transplants and root crops, and with the dust that accompanies hay and cereal crops. They can be carried from the fields in bags, crates, boxes, wagons. They can be carried on a farmer's shoes or in his pants cuffs, or on the feet of birds and animals.

The Mazoe Valley of Rhodesia affords an instance of the spread of witchweed over a sizable area. The weed was first reported there in 1916, during World War I. Nothing was done about it. By 1932, more than 70,000 acres of corn in the valley were seriously affected by the pest. In other parts of Africa the weed has been present so long that no records exist of its original infestation and spread.

Effects on Host Crops

The first effect of witchweed infestation on a host crop is what might be expected of a plant from which the juices are being robbed--it wilts. Thereafter, as more witchweed roots attach themselves to more roots of the host, the plant behaves as though it were drought-stricken--and there is no relief when it rains. South African experiments have shown that affected plants transpire or give off only half as much moisture as those not infested with witchweed. The plant suffers a sudden stunting of growth, turns yellow, then brown, and, depending on the intensity of infestation, sooner or later dies.

Early infestation may be so light as to attract little notice. But the damage is compounded in subsequent crop years. The few years' experience in this country indicates that the damage to corn increases each year and may in some cases result in complete economic loss. Losses from witchweed in grain-growing sections of the Anglo-Egyptian Sudan, according to conservative estimates, have run as high as 66 percent, and losses of one-fourth to one-third are very common.

Infestations in a field tend to develop in a circular pattern similar to the "fairy rings" made by certain fungi. The center of the circle is so heavily infested that few hosts, and consequently few witchweeds, can grow. Surrounding this rather barren center is a ring of yellowish host plants heavily parasitized by witchweed. At the outer edge of the gradually enlarging circle is flourishing witchweed in sufficiently limited numbers that it can do well on the available host plants. The host plants also bear up well because the attack is light. Outside the circle are uninfested host plants. This circular design in a field, or some modification of it, is an object of search by those making surveys to determine the extent of witchweed's occurrence. It may be possible that the circular effect is more pronounced in some parts of Africa where cultivation is done mostly by hand, whereas row cultivation by machinery in this country may tend to elongate and distort the concentric areas of infestation.

A scientist making a survey of insect and other pests of corn in Mozambique, southeast Africa, is quoted as saying that witchweed is "the worst enemy" of this crop. An authority on witchweed in the Sudan is convinced that "the damage caused by Striga qualifies it to be listed among the greater endemic crop diseases of the world."

Trap Plants

Fortunately for those combating witchweed, a number of crop plants provide a "host extract" that causes the seed to germinate but for some reason resist parasitism of their root systems. After germination, the weed tries to fasten itself on the roots of the intended host, but fails either because its ferment cannot dissolve the cell walls of these roots, or because the cell contents do not sufficiently nourish the young witchweed, or both. Babala grass (Pennisetum glaucum) was one of the first trap plants found in South Africa, and it was observed that even when the witchweed managed to penetrate the vascular system it somehow never thrived.

The South African Government has furnished, in advance of publication, the results of some later experiments that show peanuts and sunflowers cause more effective germination of witchweed even than corn, and are not parasitized by the plant. Other crop plants that induce a high germination of witchweed but are not attacked by it include cowpeas, soybeans, snapbeans, flax, and castor beans. Tobacco causes a low rate of germination, buckwheat a very low rate.

Resistant Varieties

Witchweed-resistant lines of sorghums have been known and grown on African farms for many years. They have been tested and improved by selection. These sorghums are subject to the initial attacks of the parasite but in some way they inhibit full development of witchweed plants and cause the death of many. One mark of a resistant plant is that very few witchweeds survive to reach the surrounding surface.

Studies on resistance tend to show that this quality may vary with location and with the species of Striga attacking the sorghum. For instance, certain sorghums are resistant to one species of Striga in India but the same varieties are not resistant to another closely related type of witchweed in the Sudan. Early breeding work on sorghums showed that the factor for resistance in the most highly resistant sorghums may be accompanied by undesirable agronomic traits.

Sorghum materials collected by ARS scientists in Africa include two strains of witchweed-resistant plants. So far, work on the development of sorghum hybrids in this country has not included incorporation of these qualities of resistance to witchweed. The need has not existed, however, before the current threat of witchweed's spread into sorghum-growing areas.

No resistant line of corn has been found. This plant, usually called maize outside the United States, is the only grain native to the New World that is widely grown in the Old World. The fact that it developed in a hemisphere that until now has been isolated from attack by witchweed may account for its lack of resistance to the pest. There is no record of corn hybrids recently produced in this country having been tested for susceptibility.

SOME ASPECTS OF THE PROBLEM

Value of Host Plants

WITCHWEED attacks valuable crops. Corn, sorghum, and sugarcane had an estimated production value in the crop year 1956 of $4.98 billion in the United States:

Corn.....	$4.57 billion
Sorghums	.35[1]
Sugarcane.....	.06
	4.98 billion

Source: Crop Values ... 1955 and 1956.

[1] Including sorghums for grain and forage, and sorgos for sirup, but not including sorghums for silage.

Information from foreign sources indicates that witchweed also attacks wheat, oats, barley, rye, and rice. It is not believed, however, that it will threaten small grains in this country because they mature before the weather is warm enough for germination and growth of witchweed. Since rice is grown in water in the United States, and the parasite is sensitive to waterlogged soils, it should not affect this crop.

There is no expectation that witchweed will spread over the country as a whole. Plans are being made to prevent its spread, and there are probably natural checks to its dissemination, such as climate and soil types.

World Range

In its world distribution--in tropical Africa, Saudi Arabia, India, Burma, Thailand, Cambodia, China, Java, and northern Australia--witch-

weed of the same or closely related species is a tropical or subtropical plant, existing generally between the latitudes of 30° N. and 30° S. There are some extensions beyond these latitudes, such as its growth on sugarcane south of 30° S. in Natal, Union of South Africa.

The pest stepped beyond its generally observed world boundaries when it invaded North Carolina and South Carolina. Latitude 34° N. runs through Horry County, S.C., and the southern tip of Columbus County, N.C.

Soil Preference

Reports from South Africa, where a great deal of research has been done on the weed, indicate that it prefers--but is not confined to--the lighter and sandier soils. But it has been known to thrive in heavy clay in the Anglo-Egyptian Sudan. In fact, the pest has occurred over a rather extensive range of soils in Africa, which differ widely in acidity as well as other characteristics. Unfortunately there are no close parallels between South African soils and those found at and near the infestation in this country.

The affected area in North Carolina and South Carolina is in a general region of Norfolk-Ruston soils, which are light-colored and sandy, ranging from coarse sands to fine sandy loams. Yet one of the infested counties extends into the Norfolk Sands area and two counties have predominantly peat and muck soils. The eight counties known to be infested lie more than half in areas of Norfolk-Ruston soils, about two-fifths in areas of peat-muck soils, and about one-twentieth in areas of Norfolk Sands. Witchweed has appeared predominantly on sandy soils in these counties, not on heavier soils.

If soil preference alone were the deciding factor governing the spread of witchweed--and it may prove to be an important one--the pest, if allowed to grow unchecked, might be expected to follow the general course of the Norfolk-Ruston soils, which run in an arc southward and westward from Fredericksburg, Va., through North Carolina, South Carolina, southern Georgia, northern Florida, southern Alabama and Mississippi, and--interrupted by the alluvial soils of the Mississippi River Delta--continue across Louisiana, southern Arkansas, southeastern Oklahoma, and into eastern Texas.

The Norfolk Sands occupy a relatively narrow strip through the central parts of North Carolina, South Carolina, and Georgia.

The peat and muck soils in the Carolinas extend northward to southeastern Virginia and southward to eastern Georgia.

Other factors in addition to soils will undoubtedly influence any future extension of witchweed. But soils will have a bearing. States having these three soil types normally grow 15.6 million acres of corn, 3.6 million acres of sorghums, and 346,000 acres of sugarcane.

Rainfall

Witchweed is commonly found in the so-called Maize Triangle of South Africa in the summer-rainfall area. There, it seems to thrive best in lower rainfall areas that have 18 to 20 inches of precipitation a year.

All of the States occupied in part by Norfolk-Ruston soil types have higher mean annual precipitations than areas occupied by the pest in South

Africa. They range from 30 inches a year in Texas to 55 inches in Louisiana. Meantime, the plant has been doing well in the two Carolinas, where the precipitation averages 47 and 50 inches a year.

Soil Temperature

About 3,000 soil temperature readings taken in South Africa have established this range for the germination of witchweed seeds:

No germination.....	59° F. or lower
Low germination.....	68° F.
Optimum germination....	86° - 104° F.
No germination.....	113° F. or higher

Generally similar results were found in North Carolina tests.

Soil temperature readings are not taken as a matter of course in the United States. Those that exist have been taken over a period of years, since 1888, and at various places in the country. Table 1 is a compilation of the available records from May through October, the growing season for most crops, at the same or nearly the same soil depths as those taken at Potchefstroom, South Africa. They are arranged from highest to lowest for the month of July.

CONTROL MEASURES

METHODS suggested for the control of witchweed are based on current understanding of the plant. Better methods should evolve--and be applied--as research adds new understanding of the problem. Means of control may be listed under four main heads. They are based on African experience and were recommended by a Striga Weed Conference held at Bennettsville, S.C., in December 1956, which was attended by representatives of the South Carolina Agricultural Experiment Station, the North Carolina Agricultural Experiment Station, Extension Services of both States, and the U.S. Department of Agriculture. They are:

1. Cultural methods
2. Chemical methods
3. Control of movement
4. Sanitary methods

Identification

Knowing that the pest is present and to be reckoned with is a primary step in controlling witchweed. Farmers should be advised to report to their county agricultural agent when they find witchweed or plants they believe to be witchweed.

Suspected plants should NOT be taken to the county agent.

The county agent should come to the plants.

This precaution is to prevent unintentional spreading of the seed in the course of finding out what the plant is.

Table 1.--Soil temperatures at Potchefstroom, South Africa,[1] where the witchweed flourishes, and temperatures taken at various locations in the United States

Place	Depth of reading	Temperature					
		May	June	July	Aug.	Sept.	Oct.
	Inches	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Potchefstroom, S. Afr.[2].....	2	83.3	--	84.2	--	--	--
Do.....	4	81.5	--	82.4	--	--	--
Temple, Tex.....	1	78.8	88.6	93.7	93.2	83.8	72.6
Do.....	3	78.3	86.5	92.2	93.3	83.9	73.1
Auburn, Ala.[3].....	3	72.2	74.0	86.5	82.2	75.5	64.8
Do.[4].....	3	73.8	75.0	87.5	83.2	76.2	64.8
Lincoln, Nebr.....	1	70.9	79.2	86.9	85.1	73.7	58.1
Do.....	3	69.7	78.1	85.1	84.0	73.5	59.4
Davis, Calif.[5].....	3	72.9	78.9	86.6	83.2	76.4	--
Pendleton, Oreg.[6].....	4	72.3	74.2	84.6	83.3	73.2	57.4
Fayetteville, Ark.....	5	65.5	70.7	83.3	84.9	73.9	69.6
Arlington, Va.[7].....	1	59.9	72.5	81.5	73.4	61.7	55.4
New Haven, Conn.[8].....	3	60.7	68.4	81.2	74.9	67.0	54.4
Urbana, Ill.....	1	63.0	72.6	78.2	76.2	69.0	55.5
Do.....	3	62.2	72.2	77.8	75.8	69.0	56.8
Union, S.C.[9].....	2	70.4	75.8	77.9	78.2	72.3	63.1
Lexington, Ky.....	3	62.8	74.6	77.1	76.7	73.1	58.3
Fargo, N. Dak.[10].....	1	62.3	69.7	77.0	76.4	61.2	49.8
Brookings, S. Dak.....	2	--	81.6	76.4	--	--	--
Blacksburg, Va.[11].....	3	--	--	76.4	74.3	--	--
East Lansing, Mich.[12].....	2	57.0	67.9	73.4	68.5	67.2	53.4
Do.....	4	56.4	66.4	72.8	68.1	65.9	52.8
Do.[13].....	2	58.7	70.0	76.2	70.8	68.2	54.1
Do.....	4	58.1	68.6	75.0	70.0	67.4	54.0
Fort Collins, Colo.....	3	56.5	66.7	71.4	69.3	61.1	48.3
Pullman, Wash.[14].....	1	60.2	62.7	66.0	75.4	60.2	42.0
Do.....	2	57.8	63.2	65.9	73.2	58.9	42.0
Moscow, Idaho.....	1	49.4	57.1	63.8	63.4	52.7	47.0
Do.....	3	51.2	58.0	64.1	67.5	54.6	47.8
Wooster, Ohio.....	1	50.8	62.6	63.0	62.3	--	50.4

Source: Unless otherwise identified, material in this table is drawn from Edith M. Fitton and Chas. F. Brooks, "Soil Temperatures in the United States," Monthly Weather Review, January 1931, pp. 6-16, published by the U. S. Weather Bureau. The readings given were taken over a period from 1888 to 1930.

Footnotes at top of following page.

[1] Potchefstroom, Transvaal, is at a southern latitude corresponding in northern latitude to Brownsville, Tex. "May" figures are those for November in South Africa, "July" figures those for January. They are transposed to parallel conditions in the Northern Hemisphere.

[2] Information furnished by the Government of the Union of South Africa.

[3] Sandy soil on a hill, frequently cultivated during growing season.

[4] Bottom land on the bank of a small stream.

[5] Deep recent alluvial soil, uncropped.

[6] Dry, light soil, thin grass.

[7] L. B. Olmstead, USDA, "Soil Temperature Records at Arlington Farm, Virginia," reprinted from Proceedings and Papers, First International Congress of Soil Science, 1927, Vol. I.

[8] Sandy loam, level, exposed to sun.

[9] Observations made at the Calhoun Experimental Forest, 7 miles southwest of Union, S.C., in a broomsedge field of brown loam. Geoffrey E. Greene, Soil Temperatures in the South Carolina Piedmont, Southeastern Forest Experiment Station, U.S. Forest Service, Station Paper No. 29, September 1953.

[10] Observations made in a science garden.

[11] Silt loam sod in an orchard.

[12] Loam.

[13] Sand.

[14] Bluegrass sod.

Cultural Methods

A primary consideration in any program to control a plant pest is to encourage germination of seeds already in the soil, yet prevent seed formation and seed dispersal.

A basic step to prevent seed formation is to stop growing the host crop--corn, sorghum, or sugarcane--in infested fields. The next step is to take advantage of the plant's habits of germination. This may be done by adopting locally recommended rotation practices, including the planting of small grains in the fall and following them in the next growing season with "catch" or "trap" crops. Winter cereals, such as wheat, oats, barley, and rye, usually germinate, grow, and mature at temperatures below the germination temperatures of witchweed. Hence they are not likely to be disturbed by the pest in the normal course of practical farming. No witchweed seeds germinate at 59° F. and only 3.5 percent germinate at 68° F.

The catch crop, consisting of host plants, is a certain method of obtaining germination of witchweed seeds. Sudangrass is recommended as a good catch crop. African experience has demonstrated the effectiveness of the catch crop, but it must be destroyed before the witchweed blooms and produces seed. If plowed under, the crop may have soil-amending value. In cases of light infestation, corn may be planted without plowing the crop under, provided witchweed is prevented from producing seed by the use of suitable chemical methods (see below).

Trap crops are mostly legumes. They stimulate germination of witchweed seeds and then starve the plants to death. These crops may be grown for 4 or 5 years, either alone or in rotation, before host crops such as corn or sorghum are resumed. If trap crops are to succeed as traps, they must be kept clear of crabgrass, Johnsongrass, and certain other grasses that are hosts of the witchweed. This can be done by plowing or by the use of appropriate herbicides. Reports of witchweed growing in peanuts and to-

bacco, leading to the belief that they are hosts of the pest, probably arise from witchweed's parasitism of a host grass in the crop. However, peanuts are an excellent trap crop and tobacco serves this purpose in a small way. Trap crops, if harvested, should not be moved from the infested area.

Chemical Methods

Weedkillers are effective on witchweed only if they are applied at or just before flowering, according to the results of African experiments. Pre-emergence sprays have not been effective in controlling the pest, nor have post-emergence sprays except at the flowering stage. Applied at this time, at the rate of 1 pound per acre, 2,4-D completely kills the plants that show above ground and provides protection for a month, after which witchweeds rarely appear.

If crops that may be damaged by 2, 4-D are growing nearby, witchweed on noncrop areas can be killed at or just before flowering by spraying it with 2 pounds of DNBP in 10 gallons of diesel oil mixed with 30 gallons of water per acre. This mixture requires agitation.

Chemical methods may be used in combination with other methods. For instance, if trap crops are planted, it may be necessary to use a herbicide on crabgrass, Johnsongrass, or other grasses that grow as weeds with the crop and serve as hosts of witchweed. After trap crops have been grown for 4 or 5 years and the field is planted again with corn, surviving witchweed may be eradicated by spraying. In Africa, infested soils have been cleared of the pest by this method.

When witchweed is found for the first time in a cultivated field, it should be destroyed by cultural or chemical methods before it flowers and goes to seed. Similar steps should be taken when growing nonhost crops such as cotton, tobacco, peanuts, or sweetpotatoes in *Striga*-infested fields.

Witchweed growing in uncultivated fields or along fencerows or roadsides should be treated with effective herbicides to prevent flowering and seeding.

Control of Movement

Movement of tiny witchweed seeds is to be avoided, in order to prevent the spread of the pest. Hence quarantine-like measures need to be taken early. Plants suspected of being witchweed should not be moved off the premises for any reason.

The seeds may be in soil or dust, which makes it necessary to regulate the movement of many classes of objects from infested to uninfested areas. They include:

¶ Bulbs, corms, tubers, rhizomes, and root crops.

¶ Transplants, including vegetable and tobacco plants.

¶ Nursery stock.

¶ Agricultural products such as seed cotton, tobacco, peanuts, corn, soybeans, and small grain.

¶ Hay and straw.

¶ Used crates, boxes, and bags.

¶ Farm machinery, equipment, and vehicles; road-building and construction equipment.

Sanitary Methods

Many objects that should not be moved because of possible infestation by dust or soil contaminated with witchweed seeds may be moved safely if they are properly cleaned before movement takes place. General methods of cleaning include washing and possibly heat treatments. Specific details for cleaning different categories of things have not yet been determined.

Used crates, boxes, bags, and other farm containers may be moved from infested premises after they have been thoroughly cleaned.

The same applies to trucks, wagons, tractors, farm machinery, road and construction machinery after they have been thoroughly cleaned.

Safe movement of hay, straw, transplants, and some other crops from infested areas may have to wait on research to develop means of cleaning and fumigation that are effective in dealing with seeds of the pest.

STEPS BEING TAKEN

Quarantine

A PUBLIC HEARING to consider placing a Federal quarantine on witchweed was held in Washington, D.C., January 30, 1957. This session was recessed and a final session was held March 5, 1957. Three reasons were given as to why a Federal quarantine may be desirable:

1. Witchweed is a serious threat to important crops.

2. The pest has crossed State lines.

3. There is reason to believe that other States may impose their own quarantines if a uniform Federal quarantine is not adopted.

At the two sessions, farmers, county agricultural agents, State and Federal agricultural officials, and members of Congress were heard.

There was general agreement that a Federal quarantine is necessary. North Carolina and South Carolina officials were of this opinion, as were representatives of 14 other States who attended the meeting or mailed statements. They were: Alabama, Arizona, California, Colorado, Iowa, Kansas, Louisiana, Michigan, Mississippi, Nebraska, New Jersey, Pennsylvania, South Dakota, and Virginia. The Central, Eastern, and National Plant Boards also favored a quarantine.

At the time this report was published (June 1957), quarantine methods were still being worked out by officials of the two States and the Federal Government to prevent the spread of witchweed in and between States. Among the problems to be met are the movement of soil (and witchweed

seeds) by machines and equipment used in custom baling, combining, irrigation, and tiling, and the handling of peanuts and tobacco. Tobacco poses a problem because of rain-splashed soil on the lower leaves and peanuts because of the dirt and seeds that cling to the hulls.

The terms of the quarantine to be established will undoubtedly be modified as the results of research contribute additional knowledge about the pest.

Survey

As soon as the growing season of 1957 is sufficiently advanced, teams of inspectors will embark on a detailed survey to determine as far as practicable the extent of infestation. Farmers, county agricultural agents, and others are being asked to assist in finding the weed. The hurried survey in the fall of 1956, which found 117 infested farms in 8 counties, probably revealed only part of the actual infestation.

Research

Research planned for the growing season of 1957 will wage a vigorous attack on the witchweed problem. The Agricultural Research Service is working with scientists of the North Carolina Agricultural Experiment Station and the South Carolina Agricultural Experiment Station to develop knowledge of the pest growing under American conditions. As information and techniques are developed by research in this and future years, they will be applied to control and eradication of the pest.

¶ The seed and plant in early stages of development will be studied anatomically.

¶ Chemical stimulants will be tested in an effort to find a synthetic "host extract" that will cause germination of witchweed seeds in the soil.

¶ Soil sterilants will be tried, to kill witchweeds on noncrop lands.

¶ Fumigants will be tested, to kill both seeds and weeds before emergence. Methyl bromide, one of the best-known fumigants, will be tried both in the soil and on contaminated equipment. Soil fumigants, even though they may prove relatively expensive for use on larger areas, may be particularly valuable and economically justified for use in smaller plots such as tobacco seedbeds and other areas for raising transplants.

¶ Herbicides of different kinds will be tried on witchweed, in a search for chemicals that will destroy the plant. Pre-planting, pre-emergence, and post-emergence treatments will be tested singly and in combinations.

¶ Efforts will be made to devise assay methods to determine the viability of witchweed seeds after various chemical treatments.

¶ Seed-detection methods will be investigated as an aid in determining the presence or absence of witchweed seeds in samples of soil and other materials.

¶ Catch crops, such as Sudangrass and millet, and trap crops will be tested for their efficiency in clearing the soil by germination of witchweed seed.

¶ Crop rotations will be studied in an effort to keep land in production during the existence of quarantines.

¶ Resistant lines of host plants will be sought by exposing selected strains to witchweed parasitism.

¶ Control of host weeds such as crabgrass and Johnsongrass will be attempted in connection with both cultural and chemical practices.

¶ Host-range studies will be made of major crops in the area, in an effort to determine what plants are susceptible under American conditions, what plants are trap plants, and what are not susceptible.

¶ Soil types will be tested for their effect on the growth of witchweed. Sufficient quantities of a dozen or so of the major soil types will be collected in Georgia, Indiana, Illinois, Iowa, Mississippi, and possibly other States and shipped to North Carolina. Field tests will be made of corn and witchweed growing in these soils. This year at least it will not be possible to simulate temperatures of South Africa, the Corn Belt, and other regions.

¶ Much more needs to be known about witchweed's responses to soil and climate, but this implies long-range rather than emergency research and these subjects will be studied only slightly in 1957.

THE OUTLOOK

PROSPECTS for a quick victory over witchweed are not bright. A plant that produces multitudes of seeds so feathery light and so exceedingly small that they can be spread casually into the soil and over distances will not be easily disposed of. This is especially true when these same seeds may have a patient dormancy in the soil of nearly a human generation if they are not in the meantime stimulated by the root of a host plant growing through the earth within one-tenth of an inch of them.

The extent of infestation in this country should be more nearly determined by surveys during the growing season of 1957. But, as long as the pest exists in this country, a constant lookout will be necessary to detect further spread.

Control methods, designed to lessen the immediate seriousness of infestation, can be put into effect fairly rapidly, thanks to research results supplied by the Governments of Anglo-Egyptian Sudan and the Union of South Africa. The effectiveness of these methods in this country will depend on how similarly witchweed behaves here as it does in the Old World.

Federal and State quarantines, when established, will set up barriers designed to prevent movement of seeds and to confine the pest to areas presently occupied. This will be difficult, because of the small size of the seeds, as long as any infestation remains. Within the quarantined areas, active measures will be taken to reduce the seriousness of the infestation and at the same time to permit farmers to carry on with economic pursuits.

Research projects have been planned, the results of which are expected to bring about definite improvement in the techniques of quarantine and control. But research scientists are understandably reticent about the possibility of blanketing an area so thoroughly with germinants--known or yet to be found--that the last tiny seed will sprout, and of having such watchful cooperation that the last plant will be destroyed before it goes to seed.

The most hopeful sign is the cooperative attitude of all those concerned by the invasion of this "firebrand."

☆ U. S. GOVERNMENT PRINTING OFFICE : 1957 O - 431442